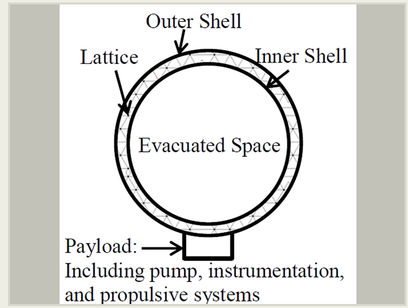
Evacuated Airship for Mars Missions

Completed Technology Project (2017 - 2018)

Project Introduction

We propose to overcome some of the limitations of current technologies for Mars exploration and even extend current operational capabilities by introducing the concept of a vacuum airship. This concept is similar to a standard balloon, whereas a balloon uses helium or hydrogen to displace air and provide lift, a vacuum airship uses a rigid structure to maintain a vacuum to displace air and provide lift.##A vacuum airship made of a homogenous material cannot withstand the atmospheric pressure on Earth for any material humans have yet discovered, which can be proven using the critical buckling load of a sphere. However, from an initial analysis of the vacuum airship structure and relationship to atmospheric conditions, Mars appears to have an atmosphere in which the operation of a vacuum airship would not only be possible, but beneficial over a conventional balloon or dirigible. In addition, a multi-layer approach, in conjunction with a lattice, would circumvent the buckling problems of a single homogenous shell. The lattice used to support the two layers of the vacuum airship shell can be made, using modulation of the lengths of the members, to fit the curvature of the vacuum airship precisely by following an atlas approach to the modulation. The Martian atmosphere has a pressure to density ratio that is very beneficial to the operation of a vacuum airship; this is a result of the high average molecular weight of the atmosphere (relative to other planets in the solar system) and the temperature of the atmosphere, the trend for which can be observed from the ideal gas law. Through a more in-depth analysis of the vacuum airship model, it can be shown that the vacuum airship may theoretically carry more than twice as much payload as a modeled dirigible of the same size, a 40-meter radius, in the Martian atmosphere.##A vacuum airship would be a valuable design for a vehicular probe for Mars. There are far fewer obstacles for an aerial vehicle as compared to a land vehicle such as existing Mars rovers, e.g. one need not worry about the vacuum airship getting stuck in a trench or being unable to traverse terrain. The vacuum airship could be used as a communication relay for other vehicular probes on Mars thereby overcoming line of sight constraints. If the vacuum airship is damaged, it can land, be repaired, and re-evacuated to resume operation, whereas a balloon would need to have gas pumped back into the vessel. Since the vacuum airship does not use a lifting gas, it can perform a near infinite number of compensation maneuvers to adjust or stabilize its altitude in a temperature variant environment. The vacuum airship could use its structure to protect the instruments from solar radiation and high energy particles. The vacuum airship probe would be able to traverse a much greater area of the planet in a smaller amount of time because there is no need to worry about getting stuck, and the vacuum airship can also observe a greater swath of land by rising in elevation. Even though the vacuum airship would be aerially base, the vehicle would still be able to touch down and perform tasks on the ground; it is even possible the vacuum airship could be used to transport ground probes to different locations. As far as energy is concerned, the large surface area of the vacuum airship would provide plenty of area for solar cells which would allow



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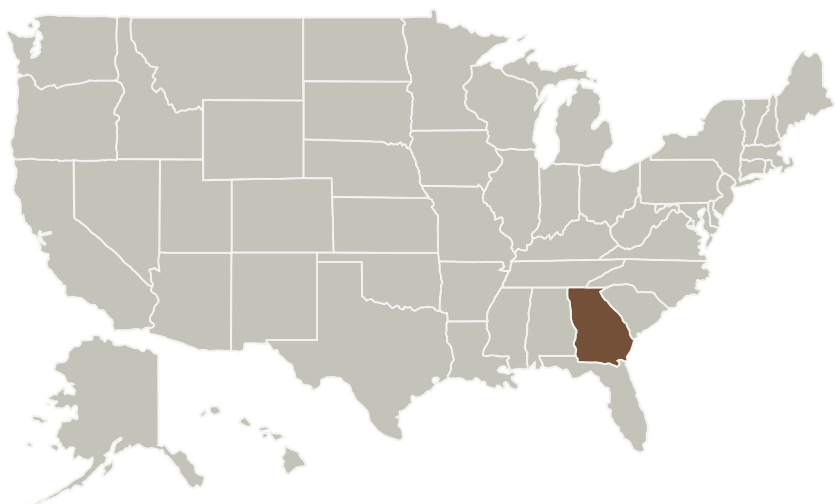
the vehicle to gather a large amount of solar energy without any additional structure, and once the airship is evacuated, the only energy it requires is for propulsion which can be accomplished by electric motors, unlike helicopters and airplanes which require energy to be devoted to lift.

Anticipated Benefits

A vacuum airship would be a valuable design for a vehicular probe for Mars.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Georgia Institute of Technology-Main Campus(GA Tech)	Lead Organization	Academia	Atlanta, Georgia

Primary U.S. Work Locations
Georgia

Project Transitions

April 2017: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Georgia Institute of Technology-Main Campus (GA Tech)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

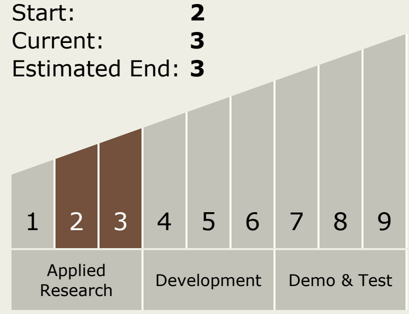
Eric A Eberly

Principal Investigator:

John-paul B Clarke

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



January 2018: Closed out

Closeout Summary: An evacuated or vacuum airship relies on the same princi ple of buoyancy used by standard balloons. However, unlike a balloon which use s a lighter than air gas to displace air and provide lift, the vacuum airship levera ges a rigid structure to maintain a vacuum and displace air, thereby providing b uoyancy. This method is similar to how a ship uses a rigid structure to displace water and fill the space with air; an evacuated airship uses the same mechanis m, except air is displaced and the space remains vacant. Using this method, the evacuated airship is capable of utilizing the full potential of the displaced mass o f air, which has interesting implications in the Martian atmosphere. Unlike other aerial vehicles, which are at a disadvantage in Martian atmospheric conditions, t he evacuated airship benefits from the Martian atmosphere by virtue of the tem perature and molecular composition. As a result, the evacuated airship offers an unprecedented payload capacity and, if implemented, may be used to transport current and future scientific instruments, other vehicles, rovers, and possibly ev en human habitations. A standard dirigible or balloon for Mars would have a sev erely limited span of operation and a very narrow field of study, nearly exclusive ly the atmosphere, but a vacuum airship can be used as a long term tool for ma ny different missions: transportation, ground study, communications, atmospher ic study, etcetera, thereby making it a far more economically sensible choice. Th is investigation illustrates development of several different approaches to the ev acuated airship which are dictated by different enabling technologies as well as t hose viable with current technology. For current materials technology, this inves tigation has addressed and solved the most core feasibility aspects of the conce pt, laying the foundation for further development of the mission and design. The current design of the evacuated airship uses a tensegrity structure, which is a tr uss structure comprised of bars in pure compression and cables in pure tension, to support an outer membrane. Beams of the tensegrity structure themselves ar e comprised of more intricate tensegrity structures, which reduce the overall ma ss of the design, enabling payload capacity. As such, this design is fully capable of supporting the load from atmospheric pressure on Mars while remaining light enough to have useful payload capacity, which was testing using detailed, non-li near finite element simulations, accounting for non-linearities in displacement, g lobal and local buckling, and membrane failure criteria. This was further improve d by combining and extending several design methods to reduce the overall mas s of the structure. As can be shown, the current payload of the design is 500 kil ograms, with projections through further implementation of the developed desig n methods to have a payload over one ton, and even more payload can be expe cted from further development of the design and mission. There still remain ma ny other avenues for further mass reduction of the structure and optimization of the design in general, which can be used in conjunction with the methods develo ped over this investigation. Additionally, protocols for the fundamentals of a mis sion implementing the evacuated airship on Mars are examined in this investigat ion. These protocols cover the transport, deployment, and planetary insertion of the evacuated airship on Mars, which are the main criteria for mission feasibility. Planetary insertion was analyzed using high fidelity numerical methods to obser ve the full scope of influences on the evacuated airship during entry into the at mosphere. As a result, the underlying analysis behind the installation of the eva cuated airship on Mars has been covered sufficiently and provides a general fra mework which is fully capable of conforming to future changes and adaptations t o the design. Overall, the evacuated airship represents an exciting and revolutio nary concept for Mars and will enable missions which would otherwise be imposs ible. Not to mention, a vast majority of the structural methods and theory devel

Technology Areas

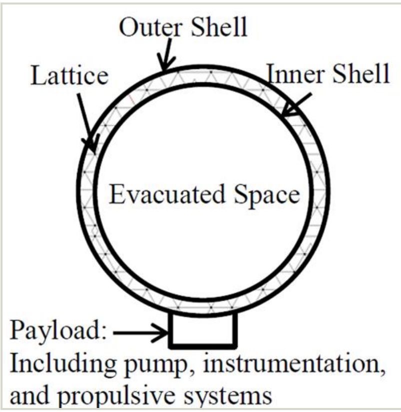
Primary:

- TX04 Robotic Systems
  └ TX04.2 Mobility
    └ TX04.2.2 Above-Surface Mobility

Target Destination

Mars

Images



Project Image
Evacuated Airship for Mars Missions
Credits: John-Paul Clarke
(https://techport.nasa.gov/image/102063)

Links

NASA.gov Feature Article
(https://www.nasa.gov/directorates/spacetech/niac/2017_Phase_I_Phase_II/Evacuated_Airship_for_Mars_Missions)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html